WATER GLOBAL PRACTICE

Water Scarcity in Morocco

Analysis of Key Water Challenges

Farzad Taheripour, Wallace E. Tyner, Iman Haqiqi, and Ehsanreza Sajedinia

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Chapter 1
Introduction

The Middle East and North Africa is one of the most water-scarce regions in the world (Rosegrant et al. 2013). In the future, like other countries of this region, Morocco is expected face a major water shortfall prompted by expansion in demand for water, reduction in precipitation induced by climate change, or both. Similar to other countries in the Middle East and North Africa region, water is mainly used for irrigation in Morocco. During the past two decades, the annual water withdrawal ranged between 11 billion and 15 billion cubic meters per year in Morocco. About 75 to 87 percent of total water withdrawal was used for irrigation (FAO 2018).

Crop production in Morocco heavily relies on irrigation because of low productivity of rainfed cropping. Although the share of irrigated crops in the total harvested area of Morocco is around 20 to 25 percent, nearly 65 percent of the monetary value of crops produced comes from irrigated crops. These figures simply indicate that major reduction in water supply could harm the level and value of agricultural production in Morocco. Beside food security concerns, this could lead to more imports of grains such as wheat and barley and could generate major economic consequences.

The share of agriculture in total gross domestic product (GDP) of Morocco usually fluctuates around 15 percent, because value added to this sector fluctuates frequently because of changes in annual rainfall (Ouraich and Tyner 2018). However, agricultural activities provide many job opportunities for a large portion of the labor force. In general, about 40 percent of the labor force in Morocco works in agricultural activities, including forestry and fishery (Danish Trade Union 2015; Ghanem 2015; HCP 2016). This share was about 38 percent at the national level in 2016. The corresponding figures for urban and rural areas were 4.5 and 72.9 percent, respectively, in that year, according to the High Commission for Planning of Morocco (HCP) report (2016). Hence, reduction in water supply could directly and indirectly eliminate job opportunities in agricultural and nonagricultural activities. In addition, a major reduction in water supply could cause idled capacity across the country, which could intensify the adverse impacts of water scarcity on the job market and GDP. The main goal of this paper is to examine the extent to which water scarcity could affect the Moroccan economy.

To accomplish this task, a well-known computable general equilibrium (CGE) model from the Global Trade Analysis Project (GTAP), dubbed GTAP-BIO-W, is used. This model traces demands for and supplies of all goods and services produced, consumed, and traded globally by country or region. It also takes into account resource constraints and models allocation of limited resources, including labor, capital, natural resources, water, and land. This model divides crop production into rainfed and irrigated and traces water and land resources and their demands at the spatial resolution of the river basin (RB) and agroecological zone (AEZ) in each country or region; for details, see Liu, Hertel, and Taheripour (2013) and Taheripour et al. (2018).

To concentrate on the economy of Morocco, the model and its database are geographically aggregated into three regions: Morocco, European Union, and other (representing the rest of the world). The GTAP-BIO-W model uses a benchmark database that represents the global economy in 2011. To provide more up-to-date analyses, this database has been updated to represent the global economy in 2016 as described in Taheripour et al. (2018) and subsequent sections.

To achieve the goals of our research, we developed a range of alternative simulations that portray the economy of Morocco under different water scarcity scenarios mixed with climate impacts on crop yields and alternative sets of economic parameters that jointly govern allocation of water across uses. We began with simulations that assess impacts of reductions in water supply at different rates. Then, we took into account impacts of climate change on crop yields. After that, we examined the extent to which improvements in water use efficiency (WUE) could mitigate the adverse impacts of water scarcity. Frequently, it is argued that an improvement in WUE (that is, producing more crops per drop of water) could lead to a rebound effect in consumption of water, which increases water withdrawal (Li and Zhao 2018; Pfeiffer and Lin 2014; Ward and Pulido-Velazquez 2008). Therefore, we developed a set of simulations to examine the extent to which WUE may generate a rebound effect in water consumption for irrigation in Morocco. Then, in a set of simulations, we showed that more flexibility in water allocation across uses may help to mitigate adverse impacts of water scarcity. In what follows, we first explain the GTAP-BIO-W model and its database. Then, we review some key characteristics of the economy of Morocco. After that, we introduce our simulation scenarios, followed by the numerical results and conclusions.

Chapter 2

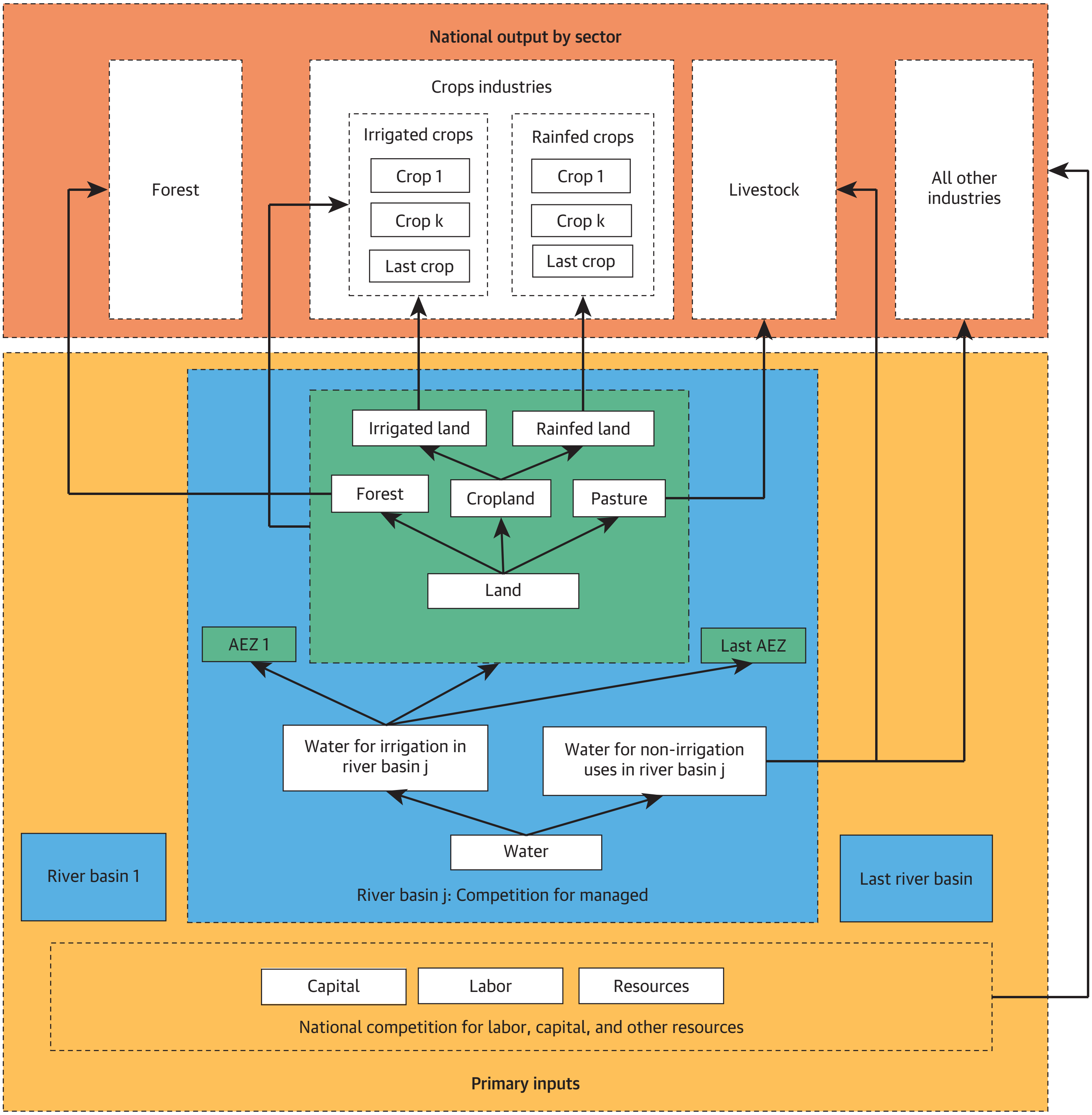
GTAP-BIO-W Model and Its Database

The latest version of the GTAP-BIO-W model and its database are explained in Taheripour et al. (2018). It is a static CGE model that combines economic and biophysical information on land and water. It is designed to examine the nexus between agricultural activities, industrial and energy sectors, and trade in the presence of climate change and water scarcity by country on a global scale. The GTAP-BIO-W model carries the following major characteristics:

- It is the only global CGE model that explicitly traces water consumption by sector and country at the RB level by AEZs. A large RB could serve several AEZs.
- It incorporates water into the production function of all economic activities, including crops, livestock, industries, and utility services. Therefore, all economic activities compete for water.
- Unlike other existing global CGE models, this model distinguishes between rainfed and irrigated crops to better capture the links between demands for irrigation and food supply.
- Nested constant elasticity of substitution (CES) production functions are used in this model.[1] Hence, it allows examination of alternative assumptions on substitution between water and other inputs, particularly for capital and land.
- This model takes into account heterogeneity[2] in the price of water and traces demand for and supply of water by country at the RB level by AEZ. This means that the marginal value of water could be different at different places and across uses.
- It uses a nested constant elasticity of transformation (CET) functional form to model the supply side of water. This approach allows us to take into account the real-world rigidities in water allocation across uses. Although some adjustment of water use across sectors is possible, it is by no means freely mobile like other mobile inputs such as labor or capital. This is a standard method to model a sluggish input like water that cannot move freely across uses and across AEZs, RBs, and regions.
- The database used in this research matches existing data provided by trusted international organizations. The biophysical information includes crop production, harvested area, land cover items, and water used, which match national and international databases, including those of the World Bank and the Food and Agriculture Organization of the United Nations (FAO). We updated this database to represent the world economy in 2016.

Figure 2.1 represents the GTAP-BIO-W approach in allocating primary inputs, including labor, capital, resources, land, and water. In this model, competition for labor, capital, and resources takes place at the national level. This means that companies compete for these primary inputs only at that level. In figure 2.1, the competition for these endowments occurs within the light yellow box, which represents a national economy, including several RBs. Sectors take labor, capital, and resources from the national pool. Labor and capital are usual mobile inputs. This means that these resources move easily across uses. Following the standard GTAP model, natural resources are modeled as sluggish endowments. This means that they cannot move freely across sectors.

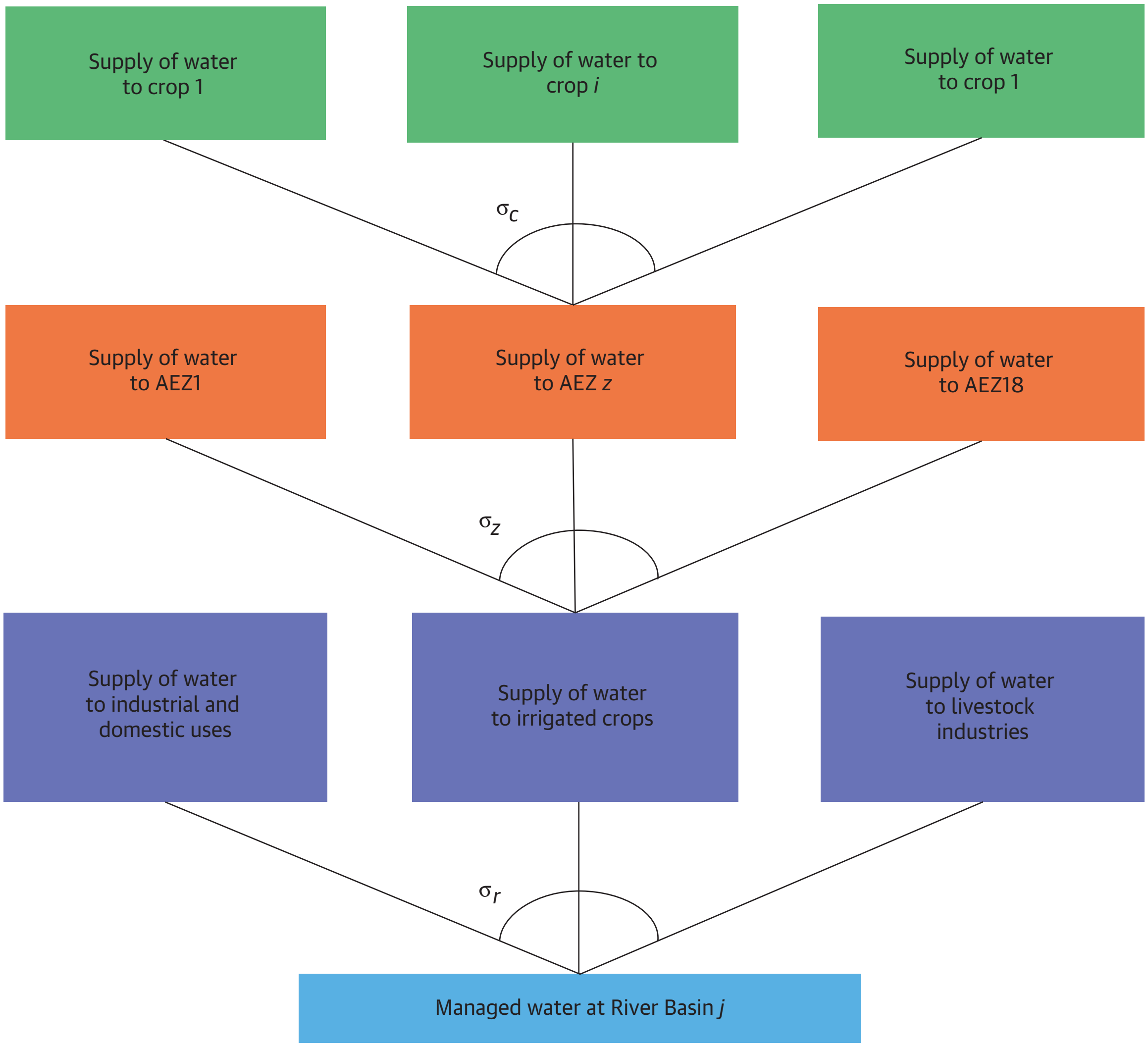
FIGURE 2.1. Structure of GTAP-BIO-W Static Model



Source: Taheripour et al. 2018. Copyright 2018 from *Routledge Handbook of Sustainable Development in Asia*, edited by Sara Hsu. Reproduced by permission of Taylor and Francis, a division of Informa plc. This permission does not cover any third party copyrighted work which may appear in the material requested. Please check the acknowledgements section of the book.

However, competition for water takes place at the RB level. As shown in figure 2.1, an economy may have several RBs. In each RB, water has two main uses. A portion of water goes toward irrigation, and the rest goes toward other uses. As shown in figure 2.1, each RB may serve several AEZs. Thus, AEZs of each RB compete for irrigation (see the blue box). The GTAP-BIO-W model also represents available managed land at the RB-AEZ level. In each RB-AEZ, the area of available managed land is divided among forest, pasture, and cropland, as shown in figure 2.1. Then, irrigated and rainfed crops compete for cropland. Land cannot move across RB-AEZs. The irrigated crops compete for managed water in each RB at the AEZ level. This means that competition for water for irrigation also takes place at the spatial resolution of RB-AEZ. Finally, irrigated crops compete for irrigated cropland and rained crops compete for rainfed cropland. In this model, water can move from one AEZ to another in an RB. Water transformation elasticity governs the movement of water across the AEZs of an RB, as explained later.

FIGURE 2.2. Water Supply in New GTAP-BIO-W Model



In the earlier version of this model, water was permitted to move freely with no restriction across the AEZs of an RB. However, water often cannot move freely within RBs because of water rights, quotas, and other constraints, so we altered the model to restrict the movement of water across the AEZs of an RB. Figure 2.2 represents the nesting structure of the supply of water in the new GTAP-BIO-W used in this research. In this nesting structure, the three parameters of σ_r, σ_z, and σ_c control the supply side of water in an RB. The first parameter, σ_r, which represents water transformation elasticity across main uses, governs the allocation of available water of an RB across three main uses: (1) water to irrigated crops, (2) water for livestock, and (3) water for industrial and domestic uses. When $\sigma_r = 0$, this means that water cannot move across the major uses in an RB. However, if $\sigma_r < 0$, then water can move across uses. The larger the magnitude of $| \sigma_r |$, the easier it is for water to move across the main uses. The second parameter, σ_z, which represents water transformation elasticity across AEZs, manages allocation of water for irrigation across the AEZs of an RB. If water cannot move across the AEZs of an RB, then $\sigma_z = 0$. The larger the absolute magnitude of σ_z, the easier it is to move water across the AEZs of an RB. For example, if moving water from one AEZ to another AEZ is costly, then the size of σ_z should be close to zero. The third parameter, σ_c, which represents water transformation elasticity across crops, allocates water across irrigated crops. If water cannot move across crops of an RB, then $\sigma_c = 0$. The larger the absolute magnitude of σ_c, the easier it is to move water across crops.

These water transformation elasticities can be used to impose any restriction on the movement of water across uses, AEZs, and crops. This setup provides a unique environment to examine all kinds of rigidities in the supply side of the market for water. Because the true values of these elasticities are unknown, the sensitivity of the model results can be tested with respect to changes in these parameters.

Similar to existing water CGE models, water is introduced into the production function of companies to determine demand for water. Three groups of users purchase managed water directly: irrigated crop sectors, livestock producers, and water utilities (Water-Util). The crop producers usually use a big portion of water withdrawal for irrigation in each RB.

The GTAP-BIO-W database represents distribution of water across the main uses in the base year according to FAO data. Each irrigated crop sector (for example, irrigated fruits) can get water from any RB-AEZ. The database determines the initial distribution of water across the RB-AEZ according to actual observations. Livestock sectors can get water from available RBs.

The Water-Util sector also can purchase water from available RBs. The database determines the initial distributions of water demanded by the livestock and Water-Util sectors. The Water-Util sector sells processed water to all other industries, households, and the government. Again, the database determines the initial distribution of water sold by the Water-Util sector.

The GTAP-BIO-W model, like any other CGE model, determines optimal allocation of all primary factors of production (including labor, land, water, capital, and resources) among their alternative uses given the existing data and model parameters. To concentrate on the economy of Morocco, the model and its database are geographically aggregated into three regions: Morocco, European Union, and other (representing the rest of the world). This aggregation highlights the role of the European Union as the main trade partner of Morocco. If needed, this aggregation allows us to study European Union and Morocco trade relationships.

The standard GTAP database aggregates all goods and services produced or provided across the world into 52 categories. The sectoral aggregation used in this research is presented in appendix A. This aggregation divides crop sectors into 12 categories, represents 3 livestock sectors, includes forestry, and covers all other economic activities aggregated into 29 sectors.

Notes

1. A nested CES production function divides production inputs into several subgroups and assigns different elasticity of substitution parameters between the inputs of each nest and among the nests.
2. In a competitive market all users of a commodity pay the same price for that commodity. When there are rigidities in the market for an endowment (or a commodity), the users pay different prices for that endowment (or commodity). This represents heterogeneity in price paid by users. For example, when water cannot freely move from agricultural uses to non-agricultural uses due to the existing restrictions (e.g., quotas, water rights, or any other social restrictions), agricultural and non-agricultural users of water pay different prices for water. In this case water is not a homogenous commodity across its alternative uses.

Chapter 3
Economy of Morocco: A Short Review

Agricultural Variables

Table 3.1 shows the shares of each crop category in total harvested area, total crop production, and total crop values of Morocco in 2016. Wheat had the largest share (39.4 percent) in harvested area of Morocco. After that, coarse grains and oilseeds had the largest shares in harvested area (29.2 and 12.2 percent, respectively). A tiny share of harvested area was allocated to sugar crops (0.8 percent). The shares of vegetables and fruits in the total area were about 10.0 and 8.3 percent, respectively, in 2016.

Crop shares in total crop production (physical quantities) are different from area shares, because crops have different yields.[1] As shown in table 3.1, the shares of wheat, coarse grains, and oilseeds in total crop production of Morocco were about 21.3, 9.4, and 5.3 percent, respectively, in 2016. The share of sugar crops was 13.5 percent, larger than the harvested area share of this crop (0.8 percent). This is because yields of sugar crops are large compared with those of other crops. The shares of vegetables and fruits in total crop production of Morocco were about 27.9 and 22.3 percent, respectively, in 2016, significantly larger than their shares in harvested area.

Finally, table 3.1 shows that vegetables and fruits have the largest share in total crop values produced in Morocco. The value shares of these two crop categories were 36.7 and 30.6 percent, respectively, in 2016. The value shares for wheat, coarse grains, oilseeds, and sugar crops were about 11.7, 4.3, 14.3, and 2.4 percent, respectively, in this year. These figures confirm that vegetables and fruits are the most productive and valuable crops produced in Morocco.

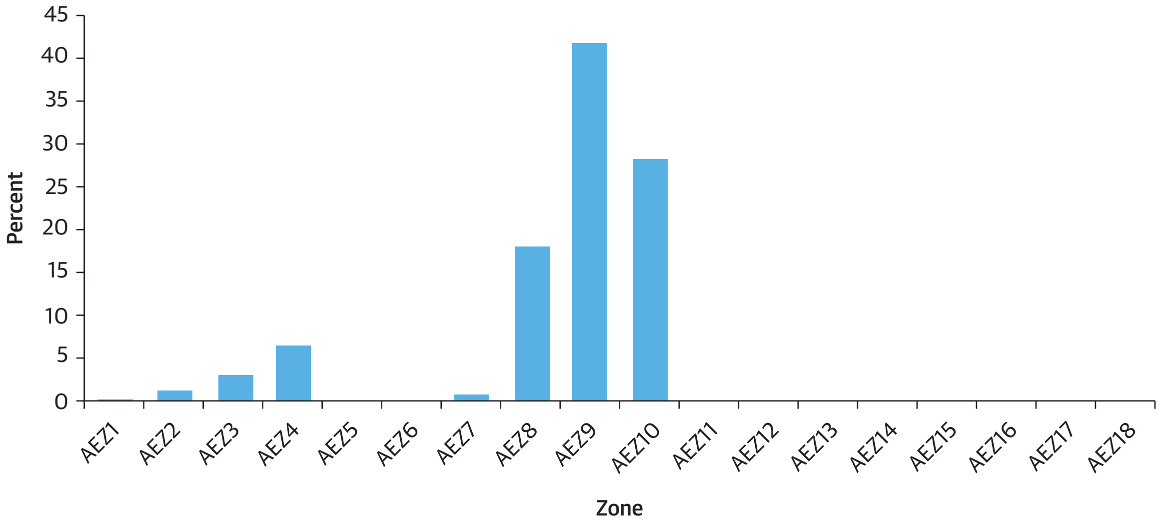
In addition to domestic production, Morocco imports several crops from other countries. The main imported crops are usually wheat and coarse grains. The joint share of these two crop categories in total imports of crops of Morocco was around 75 percent in 2016. However, Morocco basically exports vegetables and fruits to other countries (largely to the European Union).

TABLE 3.1. Crop Shares in Harvested Area, Crop Production, and Crop Values, Morocco, 2016

Crops	Shares in harvested area (%)	Shares in production (%)	Shares in value of production at producer prices (%)
Wheat	39.4	21.3	11.7
Coarse grains	29.2	9.4	4.3
Oilseeds	12.2	5.3	14.3
Sugar crops	0.8	13.5	2.4
Vegetables	10.0	27.6	36.7
Fruits and others	8.3	22.9	30.6
All crops	100.0	100.0	100.0

Source: Food and Agriculture Organization Corporate Statistical Database; GTAP-BIO-W database.

FIGURE 3.1. **Distribution of Harvested Area across AEZs, Morocco, 2016**



Source: GTAP-BIO-W database.

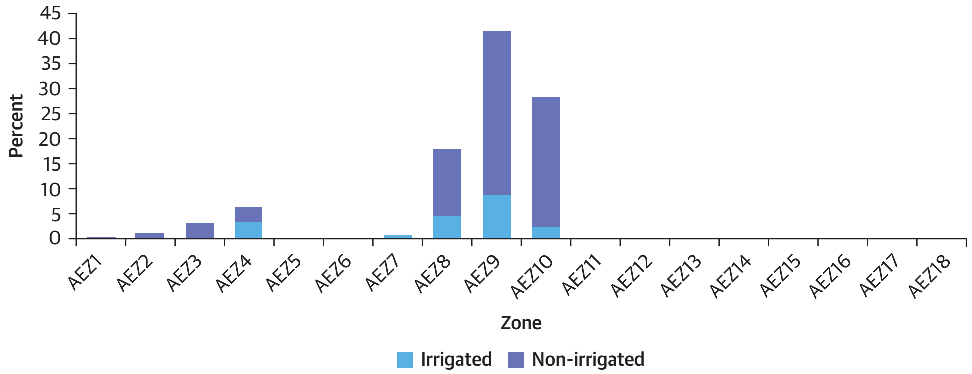
Over time, Morocco shifted its available agricultural resources to produce more valuable exportable crops, such as vegetables and fruits. Instead, it imported more wheat and coarse grains from the world market. Yields of wheat and coarse grains in Morocco are low compared with world averages. Morocco's wheat yield was about 37 percent of the world average yield for 2016. The corresponding figure for coarse grains was 23 percent.

The available cropland in Morocco is scattered across AEZs, as shown in figure 3.1. However, croplands are basically located in AEZ8 (very dry), AEZ9 (moist and semiarid), and AEZ10 (warm, temperate, and dry). The shares of these AEZs in the total area of cropland of Morocco are about 18, 42, and 28 percent, respectively. Morocco also has some cropland in AEZ1 to AEZ4, as shown in figure 3.1. These tropical AEZs represent arid to subhumid moisture regimes and jointly cover 11 percent of the total area of cropland in Morocco.

In general, the total area of cropland of Morocco is about 9.6 million hectares (FAO 2016). Usually, a portion of available cropland (about 15 to 20 percent) remains uncultivated each year in Morocco. The area of irrigated cropland in Morocco is about 1.5 million to 1.7 million hectares. Only a small portion of irrigated cropland is equipped with advanced irrigation systems (for example, sprinkler or drip irrigation systems). The government of Morocco plans to support farmers to install advanced irrigation systems. The goal of the government is to install advanced irrigation systems on about 555,000 hectares of irrigated land. With this plan, the share of irrigated cropland equipped with advanced irrigation technologies will reach 55 to 60 percent of the total area of irrigated land (African Development Bank 2016; Berrada 2009).

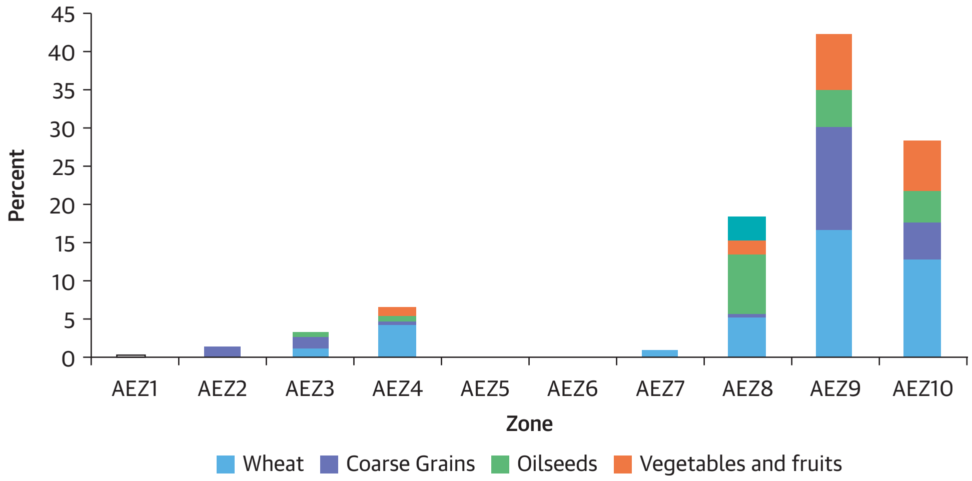
Irrigation varies across AEZs in Morocco, as shown in figure 3.2. Around 44.0 percent of irrigated harvested area (9.0 percent of irrigated and rainfed harvested areas) is in AEZ9, followed by AEZ8 with 24.0 percent of irrigated area cropland (4.8 percent of irrigated and rainfed harvested areas). AEZ4 has a little more irrigated land compared with AEZ10. This AEZ has 18.0 percent of the irrigated harvested area (12 percent of irrigated and rainfed harvested areas).

FIGURE 3.2. Distribution of Land among AEZs, by Irrigation Type, Morocco, 2016



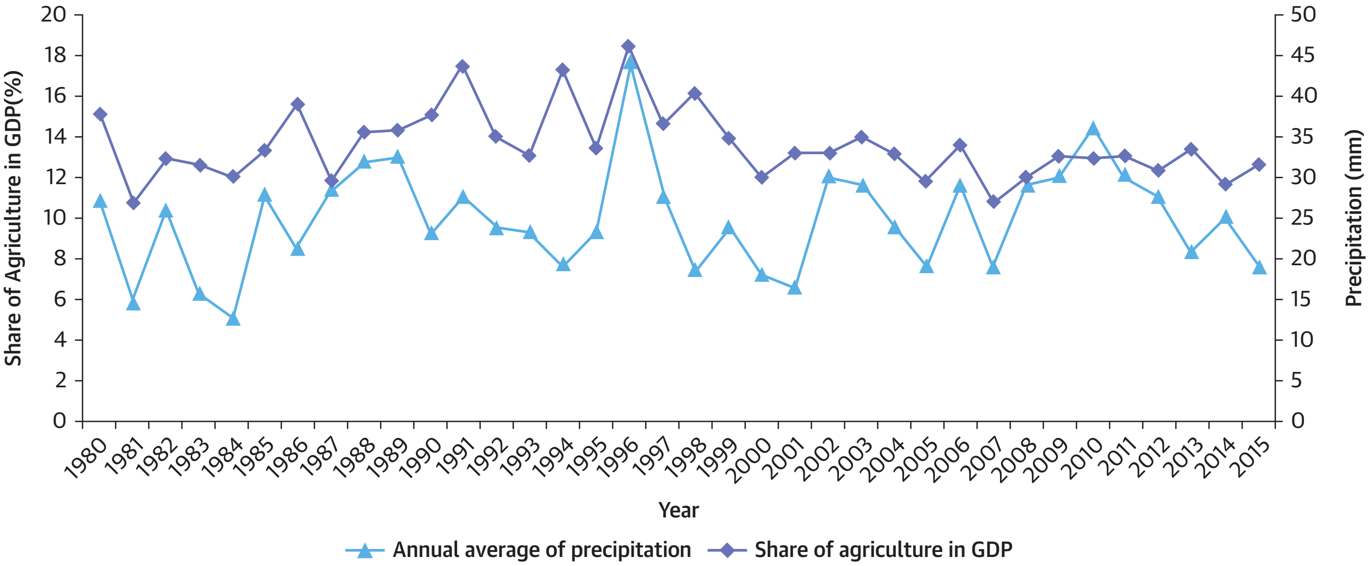
Source: GTAP-BIO-W database.

FIGURE 3.3. Distribution of Land Among AEZs, by Crop Categories, Morocco, 2016



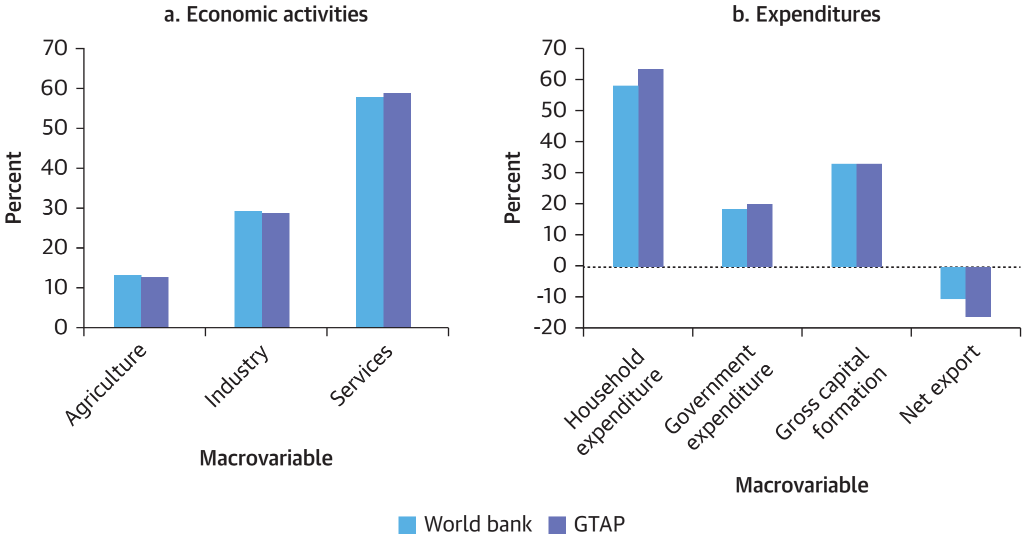
Source: GTAP-BIO-W database.

FIGURE 3.4. **Precipitation and Share of Agriculture in GDP, Morocco, 1980–2015**



Source: World Bank data.

FIGURE 3.5. **Distribution of GDP, by Economic Activities and Expenditures, Morocco**



Sources: GTAP-BIO-W database and World Bank data.

Figure 3.3 shows the distribution of harvested area of Morocco among crops by AEZ. As shown figure 3.3, wheat and coarse grains have large shares across all AEZs. Then, oilseeds, vegetables, and fruits have large shares in AEZ8, AEZ9, and AEZ10.

Beside the long-term reduction in water supply, annual changes in rainfall affect value added by the agricultural sector year by year, as shown in figure 3.4. When rainfall drops, the share of agriculture in the GDP falls as well, with some exceptions. Morocco produces low-yield rainfed grains (mainly wheat, barely, and other coarse grains). With proper rainfall, these crops perform well and contribute more to the overall value added by agricultural activities. When rainfall is insufficient or drought occurs, then the value added by the agricultural sector of Morocco drops.

Macroeconomic Variables

The GDP of Morocco was about $103,606 million in 2016. In this year, the share of agricultural value added to the GDP of Morocco was around 13 percent. The shares of industrial activities and services in the GDP were around 29 and 58 percent, respectively, in 2016, as shown in figure 3.5. Figure 3.5, panel a, shows that the World Bank and GTAP data sets represent similar figures for the distribution of the GDP across the main economic activities. Finally, consider the distribution of the GDP across uses: private consumption (62 percent), government expenditures (20 percent), investment (35 percent), and net trade (−17 percent). This means that Morocco had a trade deficit in 2016.

Note

1. Yields are measured in tonnes per hectare for all crops.

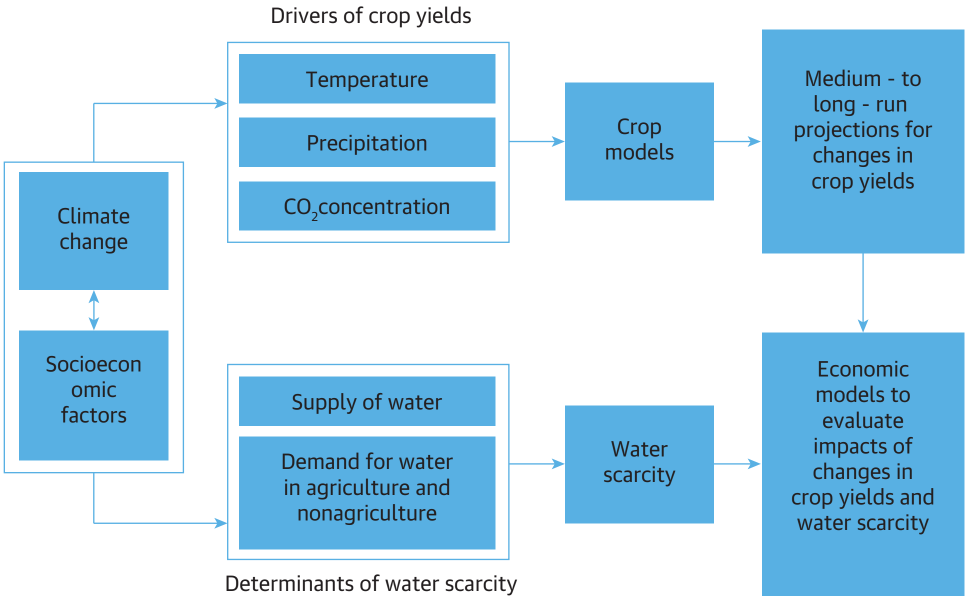
Chapter 4
Climate Change, Crop Yield, and Water Scarcity

There is extensive literature that addresses the worldwide impacts of climate change and its variability on agricultural activities (a few important examples are Fischer et al. 2005; Nelson et al. 2010; Parry et al. 2004; Reilly et al. 2003; Rosegrant et al. 2013; Rosenzweig et al. 2002, 2014). This literature highlights two different but related research topics.

The first topic reflects the worldwide implications of the future changes in temperature, precipitation, and carbon dioxide (CO_2) concentration for crop yields under alternative representative concentration pathway (RCP) scenarios. The research on this topic usually uses crop models to project future changes in crop yields under each RCP scenario (see the top boxes in figure 4.1). Rosenzweig et al. (2014) have highlighted the most recent projections in this area. Although these projections take into account future changes in precipitation and their impacts on crop yields, they do not take into account availability of water for irrigation.

Climate change impacts on irrigation water requirements and changes in water availability for irrigation is the second research topic that examines the link between agriculture and climate change. This line of research examines the extent to which climate change, in combination with other factors, alters availability of water for irrigation. Climate change could alter demand for irrigation in two main ways. On one hand, it could increase the water requirement for each crop because of changes in temperature and other biophysical conditions. It also could encourage farmers to shift toward irrigation for mitigation purposes. On the other hand, climate change could alter the supply of water across the world (Rosegrant et al. 2013). A permanent reduction in rainfall could occur because of climate change, which

FIGURE 4.1. Impacts of Climate Change, Variability on Agricultural Activities, and Economywide Consequences



would limit availability of water for irrigation. Available water for irrigation may also fall because of expansion in demand for water for nonagricultural uses. The second line of research highlights these implications (for example, see Fischer et al. 2005 and Rosegrant et al. 2013), as shown in the bottom boxes in figure 4.1. In what follows, we first examine the extent to which water scarcity and changes in crop yields because of climate change may individually and jointly affect the economy of Morocco in terms of a medium-run time horizon.

Chapter 5
Examined Scenarios

The existing literature confirms that Morocco has shifted toward warmer and drier climates in the twentieth century (Born et al. 2008; Brahim et al. 2017). Temperature is expected to increase and precipitation is expected to drop in the future in Morocco (Born et al. 2008; Brahim et al. 2017; McSweeney, New, and Lizcano 2009; Ouraich 2010; Rochdane et al. 2012). The extent to which rainfall is expected to decrease in the country varies across climate scenarios and time horizons. Ouraich (2010) concluded that scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) projected that rainfall will drop by 20 percent until 2050 and then decrease by more than 40 percent. In line with this conclusion, the United Nations Development Program projected that rainfall will drop by 15 to 25 percent in the future. Because the intensity of reduction in water supply and its time horizon are uncertain, we begin our analyses with four scenarios that show impacts of reductions in water supply from 10 to 25 percent with 5 percent increments. We refer to these simulations as S1 to S4.

The existing literature confirms that climate change will affect crop yields across the world mainly through changes in temperature. However, the impacts of climate change on crop yields vary by region and crop. In a seminal work, Rosenzweig et al. (2014) have shown that some regions or crops will gain from climate change and some will suffer. These authors have evaluated the impacts of climate change on crop yields for a range of climate scenarios and several general circulation models (GCMs) and crop models on the global scale at 0.5 by 0.5 degree resolution. In a research project developed for the World Bank, Ouraich (2010) used the same source of data and summarized the existing projections for Morocco. This author concluded that yields for rainfed crops produced in Morocco on average will drop by 15 percent until 2050. However, yields will increase for irrigated crops by 5 percent on average. We use these results and imposed exogenous shocks in productivity of the corresponding crops to reflect changes in crop yields because of climate change for Morocco. We examined these experiments in combination with water scarcity cases (that is, cases S1 to S4). Hence, the second set of simulations represent impacts of water scarcity plus yield changes induced by climate change. We refer to these simulations as SC1 to SC4.

One option for dealing with water scarcity is to improve WUE. Using advanced irrigation technologies (for example, sprinkler and drip irrigation) is a common approach to reduce water used in irrigation (Schoengold and Zilberman 2007; Zilberman, Zhao, and Heiman 2012). All other things being equal, an improvement in WUE because of advanced irrigation technologies could save water on existing land. The saved water could be used to expand irrigated area, allocate water to noncrop activities, or allocate water to conservation goals. However, an improvement in WUE may generate some rebound effect in water consumption, which may lead to expansion in water consumption (Li and Zhao 2018; Pfeiffer and Lin 2014; Ward and Pulido-Velazquez 2008).

The National Irrigation Water Saving Program (known as PNEEI) implemented by the government of Morocco supports farmers to install advanced irrigation technologies in the country (African Development Bank 2016; Berrada 2009). This program is expected to significantly improve WUE in irrigation in Morocco. The goal of this program is to reduce the share of flood irrigation in total irrigated land from 81 to 43 percent by installing advanced irrigation technologies (sprinkler and drip irrigation) on about 555,000 hectares of irrigated land (Berrada 2009). This will improve water WUE of irrigation in Morocco from 37 to 57 percent, an increase of 20 percent. To examine the extent to which this program can eliminate the adverse impacts of water scarcity and climate change we imposed a 20 percent improvement in productivity of water used in irrigated crop sectors. We added this shock onto the shocks for water scarcity and changes in crop yields because of climate change. Henceforth, we refer to these cases as SC1-W20 to SC4-W20.

Although the PNEEI program plans to achieve 20 percent improvement in WUE, it may only partially achieve this goal, because improvements in upstream irrigated areas may reduce available water for irrigation in downstream areas. In addition, although the program tends to improve WUE on the farm level, water losses in transition lines and canals may drop over time, which may eliminate a portion of the saved water on farms. Therefore, we repeated the WUE simulations with a 10 percent improvement. We refer to this simulation as SC1-W10 to SC4-W10.

In all simulations introduced so far, we assumed water supply will drop because of climate change. When the total supply of water is fixed or declining, at the national level, an expansion in WUE will not generate a rebound effect in water consumption. However, in the real world, although rainfall drops over time, which limits available surface water, crop producers may shift toward underground water to reduce the severity of water scarcity in Morocco. If that happened on a large scale, then an improvement in WUE may generate some rebound effect in consumption of water for irrigation. To examine the potential for a rebound effect in consumption of water in irrigation, we developed a set of simulations that allow water supply to change in response to improvements WUE. In these simulations, we first examined improvements in WUE at different rates: from 5 to 20 percent by 5 percent increments. We call these cases R1 to R4. Then, we assumed that productivity of rainfed crops versus irrigated crops will drop by 5 percent to examine the potential impacts of changes in crop yields induced by climate change on demand for water and rebound effect. We refer to these cases as RC1 to RC4.

To reflect rigidities in allocation of water across uses, a tiny amount of water transformation elasticity (close to zero) is applied to limit movement of water between irrigation and other uses in all examined simulations. In addition, we applied tiny substitution elasticities among primary inputs in crop sectors in this set of simulations to represent limited mitigation options and endogenous technological progress in crop production in the short run. In these simulations, we also assumed unemployment in markets for unskilled and skilled labor and capital to take into account that a major shortfall in water supply could lead to unemployment in markets for capital and labor, which generates idled capacities in agricultural and nonagricultural activities.[1]

As mentioned previously, in all simulations introduced earlier, we used limited substitution elasticities among primary inputs in crop sectors and assumed no water movement between irrigation and other activities. We changed this setup in a simulation that allows water to move between irrigation and other uses and makes it possible to substitute water-land with other primary inputs. We examine this case with a 25 percent reduction in water supply combined with changes in crop yields, as explained for the case of SC4. We refer to the last simulation as SC4-Flexible.

Note

1. A major reduction in water supply simply idles a portion of infrastructure. With reduction in available water, dams may not operate at full capacity; water infrastructure (canals, pipelines, pumps) became idled or partially idled; agricultural equipment, facilities, and machinery became useless; households leave rural areas and rural houses and roads became fully or partially idled; and many more. One can consider all of these as unemployment in capital market.

Chapter 6
Simulation Results

In what follows, we present the results in three sections. The first section examines the cases with reduction in water supply in the absence or presence of changes in crop yields (that is, S1 to S2 and SC1 to SC4). This section also covers the cases that examine improvements in WUE when water supply is decreasing and crop yields are changing (that is, SC1-W20 to SC4-W20 and SC1-W10 to SC1-W10). The common theme among all of these cases is that water supply is decreasing. The second section covers the cases that explore potentials for rebound effect in water consumption because of WUE (that is, cases R1 to R4 and RC1 to RC4). In these cases, supply of water can respond to WUE. Finally, the third section provides the results that allow movement of water between irrigation and non-irrigation uses and take into account substitution among primary inputs in crop production in the long run.

Results when Water Supply Is Decreasing

The results of the examined cases provide changes in many variables. In what follows, we only review changes in the following: GDP, share of agriculture in the GDP, employment (skilled and unskilled labor), irrigated and rainfed harvested area, and indexes of consumer and producer prices.

Impacts on the GDP

Table 6.1 shows the impacts of water scarcity on the GDP for the water scarcity cases (that is, S1 to S4) and for the cases that take into account water scarcity combined with changes in crop yields induced by climate change (that is, SC1 to SC4). As shown in table 6.1, a 10 percent reduction in water supply reduces the GDP at constant prices by 1.9 percent. This is equal to a reduction in the GDP by $1.994 million at 2016 constant prices. In a comparative static framework, this change represents a permanent reduction in the GDP compared with the baseline. All other things being equal, this means that a reduction in water supply by 10 percent drops the GDP of Morocco to a lower level, with an annual opportunity cost of $1.994 million. After that, water scarcity reduces the GDP at a relatively constant rate as the rate of reduction in water supply grows from 10 to 25 percent. With a 25 percent reduction in water scarcity, GDP drops by 5.3 percent compared with the base, or about $5.504 million at constant prices of 2016 per year.

TABLE 6.1. Changes in Real GDP Due to Reductions in Water Supply with and without Crop Yield Changes because of Climate Change

		Reduction in water supply (%)			
Examined variable	**Examined case**	**10**	**15**	**20**	**25**
Percent change in real GDP	S1 to S4	−1.9	−3.0	−4.1	−5.3
	SC1 to SC4	−4.3	−4.8	−5.5	−6.5
Change in real GDP (US$, millions)	S1 to S4	−1.994	−3.095	−4.266	−5.504
	SC1 to SC4	−4.438	−4.989	−5.746	−6.736

TABLE 6.2. Changes in Real GDP Due to Reductions in Water Supply with and without Crop Yield Changes and with Improvements in WUE

		Reduction in water supply			
Examined variable	**Examined case**	**10%**	**15%**	**20%**	**25%**
Percent change in real GDP	SC1-W20 to SC4-W20	−3.8	−4.0	−4.3	−4.8
	SC1-W10 to SC4-W10	−3.9	−4.2	−4.7	−5.4
Change in real GDP (US$, millions)	SC1-W20 to SC4-W20	−3.911	−4.118	−4.448	−4.952
	SC1-W10 to SC4-W10	−4.045	−4.390	−4.902	−5.634

These results do not represent the temporary impacts of a drought on the GDP. In a typical drought year, the economy loses a portion of its agricultural products temporally with a major shock in crop prices. After that, production returns to its usual condition and crop prices drop. However, a permanent reduction in water resources could harm the capacity of food production and reduce the national income in a medium- to long-run time frame.

When we bring the impacts of climate change on crop yields into the picture (in cases SC1 to SC4), GDP drops more compared with S1 to S4, as shown in table 6.1. In the presence of climate change, a 10 percent reduction in water supply drops the GDP by 4.3 percent. With a 25 percent reduction in water supply, the reduction in the GDP at constant prices in the presence of climate change is about 6.5 percent. This is an approximately $6.736 million reduction in the GDP per year at 2016 constant prices.

We now examine the extent to which WUE can affect the results. Table 6.2 shows the changes in the GDP for the scenarios in which we impose 20 and 10 percent improvements in WUE on the top of the shocks to the water supply and crop yields. The first two rows of table 6.2 show the percent changes in the GDP for the 20 and 10 percent improvements in WUE. These results can be compared with the results presented in the second row of table 6.1.

This comparison reveals three important findings: (1) an improvement in WUE could eliminate a portion of the negative impacts of water scarcity and climate change on the GDP; (2) the higher the rate of improvement in WUE, the higher the benefits; and (3) the benefits of WUE increase at an increasing rate as the rate of water scarcity grows. The first two findings are straightforward. Figure 6.1 represents the third finding and compares the second row of table 6.1 (results for cases SC1 to SC4) with the first row of table 6.2 (results for cases SC1-W20 to SC2-W20).

Figure 6.1 shows that at higher rates of reduction in water supply, the improvement in WUE is more effective in preserving the change in the GDP. The monetary contributions of the 20 percent improvement in WUE at 10 and 25 percent reductions in water supply are about $527 million and $1.758 million, respectively. If the PNEEI program leads to a 10 percent improvement in WUE, then its annual benefits will drop to $393 million and $1.103 million for the 10 and 25 percent reductions in water supply, respectively.

Impacts on the Share of Agriculture in the GDP

Reduction in water supply and changes in crop yields negatively affect agricultural and nonagricultural activities. However, agricultural activities suffer more; therefore, their share in the GDP drops. Figure 6.2 represents the share of agricultural activities in the GDP for two sets of simulations: reduction in water supply at different rates (cases S1 to S4, red bars in figure 6.2) and reduction in water supply combined with the changes in crop yields because of climate change (cases SC1 to SC4,: blue bars in figure 6.2).

Figure 6.2 shows that the share of agriculture in the GDP drops as the level of water scarcity increases. The share of agriculture in the GDP drops from about 13 percent in the base to nearly 11 percent for the case of 25 percent reduction in water supply. However, when the reduction in water supply is combined with the changes in crop yields, the share of the GDP drops to nearly 10.5 percent, regardless of the level

FIGURE 6.1. Changes in GDP at Constant Prices with and without WUE

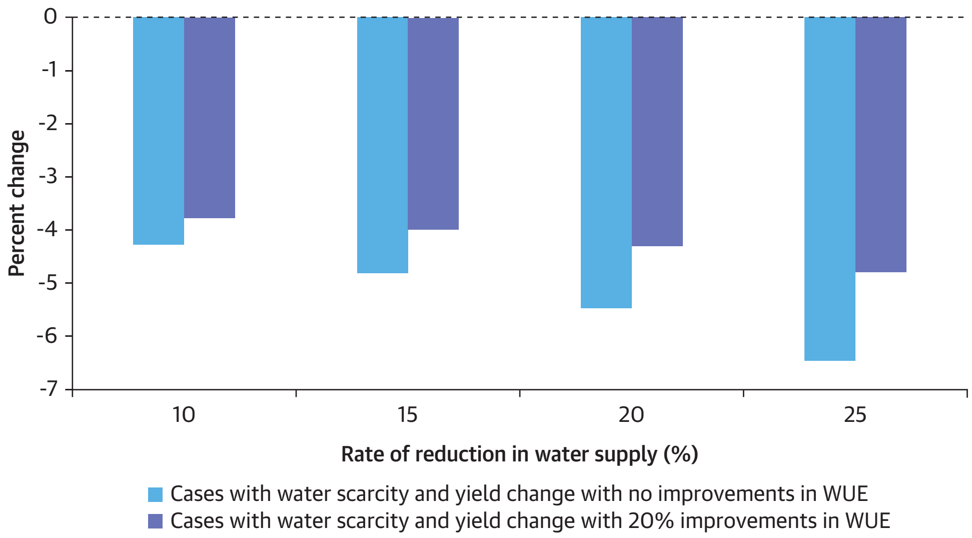
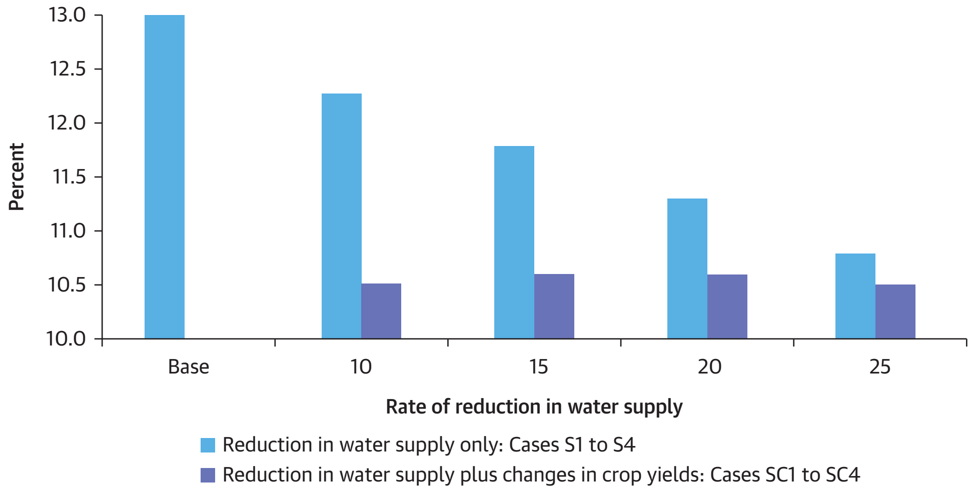


FIGURE 6.2. Share of Agriculture in GDP, S1 to S4 and SC1 to SC4



of water scarcity. A reduction in water supply negatively affects irrigated crops, but climate change improves irrigated crop yields and reduces rainfed crop yields. Therefore, the overall negative impact of these two forces on the agricultural activities is stronger than the impacts of water scarcity alone. However, the combination of these two factors pushes water and land resources toward more productive crops at higher rates of reduction in water supply, which smooths out the share of agriculture in the GDP as the economy moves from a 10 percent reduction in water supply toward a 25 percent reduction. Our test simulations (not included in this report) show that if the reduction in water supply goes beyond 25 percent, the share of agriculture in the GDP begins to drop more.

The bottom line is that agricultural activities in Morocco are faced with two forces: reduction in water supply and losing yield on rainfed land because of climate change. At lower levels of water scarcity, moving water and land toward more valuable and productive crops with a lower rate of water requirement can partially eliminate some adverse impacts of climate change. However, as the economy moves to higher rates of reduction in water supply, the mitigation options become less available.

Impacts on Demand for Labor

Nearly 40 percent of the labor force of Morocco works in agriculture, and the unemployment rate is high for unskilled and skilled labor (Danish Trade Union 2015; Ghanem 2015; HCP 2016). Here, we examine the changes in demand for unskilled and skilled labor for the examined cases in this section, as presented in tables 6.3 and 6.4. In general, reductions in agricultural activities induced by water scarcity and climate change reduce demand for unskilled and skilled labor in agricultural and in nonagricultural activities.

From the results provided in table 6.3, the following deductions can be made for unskilled labor:

- Reduction in water supply reduces demand for unskilled labor in agriculture, from −3.1 for a 10 percent reduction in water supply to −8.4 for a 25 percent reduction in water supply.

TABLE 6.3. Changes in Demand for Unskilled Labor under Alternative Scenarios

		Reduction in water supply			
Examined variable	**Examined case**	**10%**	**15%**	**20%**	**25%**
Changes in demand for unskilled labor in agricultural activities (%)	S1 to S4	−3.1	−4.8	−6.6	−8.4
	SC1 to SC4	−7.3	−7.8	−8.6	−9.7
	SC1-W20 to SC4-W20	−7.4	−7.3	−7.4	−7.7
	SC1-W10 to SC4-W10	−7.2	−7.3	−7.7	−8.4
Changes in demand for unskilled labor in nonagricultural activities (%)	S1 to S4	−1.9	−3.0	−4.1	−5.3
	SC1 to SC4	−4.0	−4.6	−5.3	−6.3
	SC1-W20 to SC4-W20	−3.5	−3.7	−4.0	−4.5
	SC1-W10 to SC4-W10	−3.6	−4.0	−4.5	−5.2
Changes in demand for unskilled labor in all economic activities (%)	S1 to S4	−2.2	−3.4	−4.6	−6.0
	SC1 to SC4	−4.7	−5.2	−6.0	−7.0
	SC1-W20 to SC4-W20	−4.3	−4.4	−4.7	−5.2
	SC1-W10 to SC4-W10	−4.3	−4.6	−5.1	−5.9

- Adding changes in crop yields extends the rate of reduction in demand for unskilled labor in agricultural activities. For example, in this case, the rate of reduction is about −9.7 percent for a 25 percent reduction in water supply.
- Improvements in WUE only partially eliminate some adverse impacts of the joint forces of water scarcity and changes in crop yields. This means that WUE alone may not effectively improve employment.
- Under alternative cases, the rates of reduction in demand for unskilled labor in nonagricultural activities are usually smaller than their rates for agriculture.
- Finally, water scarcity and climate change jointly drop demand for unskilled labor in Morocco at considerable rates. For example, a 25 percent reduction in water supply and changes in crop yields jointly drop Morocco's demand for unskilled labor by −7 percent.

From the results provided in table 6.4, the following deductions can be made for skilled labor:

- Reduction in water supply reduces demand for skilled labor in agriculture, from about −2.2 percent for a 10 percent reduction in water supply to −6.0 percent for a 25 percent reduction in water supply. These figures are smaller than those for unskilled labor by about one-third.
- Adding changes in crop yields extends the rate of reduction in demand for skilled labor in agricultural activities. For example, in this case, the rate of reduction is about −6.4 percent for a 25 percent reduction in water supply. Again, this figure is smaller than its unskilled labor counterpart by one-third.
- Similar to the case of unskilled labor, improvements in WUE only partially eliminate some adverse impacts of the joint forces of water scarcity and changes in crop yields on skilled labor. However, compared with the case of unskilled labor, improvements in WUE provide more job opportunities for skilled labor in agricultural activities.

TABLE 6.4. Changes in Demand for Skilled Labor under Alternative Scenarios

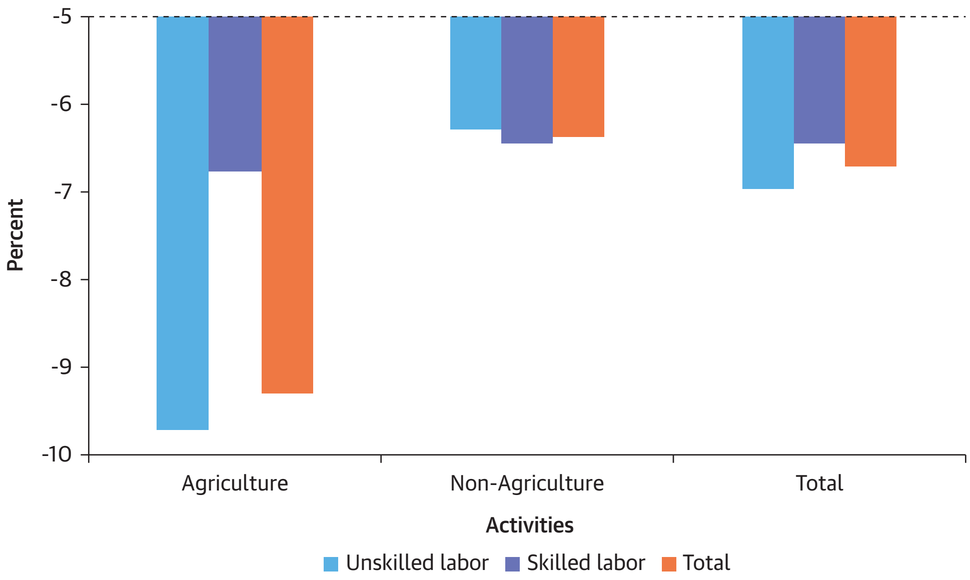
		Reduction in water supply			
Examined variable	**Examined case**	**10%**	**15%**	**20%**	**25%**
Changes in demand for skilled labor in agricultural activities (%)	S1 to S4	−2.2	−3.4	−4.6	−6.0
	SC1 to SC4	−4.5	−5.0	−5.8	−6.8
	SC1-W20 to SC4-W20	−4.2	−4.3	−4.5	−5.0
	SC1-W10 to SC4-W10	−4.2	−4.5	−4.9	−5.6
Changes in demand for skilled labor in nonagricultural activities (%)	S1 to S4	−2.0	−3.0	−4.2	−5.4
	SC1 to SC4	−4.1	−4.7	−5.5	−6.4
	SC1-W20 to SC4-W20	−3.6	−3.8	−4.2	−4.7
	SC1-W10 to SC4-W10	−3.7	−4.1	−4.6	−5.4
Changes in demand for skilled labor in all economic activities (%)	S1 to S4	−2.0	−3.0	−4.2	−5.4
	SC1 to SC4	−4.2	−4.7	−5.5	−6.5
	SC1-W20 to SC4-W20	−3.6	−3.8	−4.2	−4.7
	SC1-W10 to SC4-W10	−3.8	−4.1	−4.6	−5.4

- Similar to the case of unskilled labor, under alternative cases, the rates of reduction in demand for skilled labor in nonagricultural activities are usually smaller than their rates for agriculture. However, the gap between the rates for agricultural and nonagricultural activities for skilled labor are smaller under all examined cases.
- Finally, water scarcity and climate change jointly drop demand for skilled labor moderately. For example, a 25 percent reduction in water supply in combination with changes in crop yields drops Morocco's demand for skilled labor by −6.5 percent. This is smaller than the 7 percent rate for unskilled labor.

Figure 6.3 summarizes the joint impacts of a reduction in water supply by 25 percent and changes crop yields induced by climate change (case SC4) for skilled labor, unskilled labor, and their total for agricultural and nonagricultural activities. Given that, currently, the economy of Morocco is suffering from a significant rate of unemployment, reduction in water supply and changes in crop yields because of climate change are expected to worsen the rate of unemployment considerably.

In addition, the impacts of a temporary interruption in production of agricultural products on the labor market (for example, because of a drought) could be different from the impacts of permanent losses in agricultural production capacities. For a short-term interruption, an agricultural producer may temporarily adjust demand for labor, which may lead to a higher unemployment rate in agriculture for a short period. However, permanent reductions in water supply or crop yields because of climate variables will shrink job opportunities in agricultural activities and perhaps expand migration to urban areas.

FIGURE 6.3. Impacts of a 25 Percent Reduction in Water Supply with Crop Yield Changes on Labor Demand, SC4



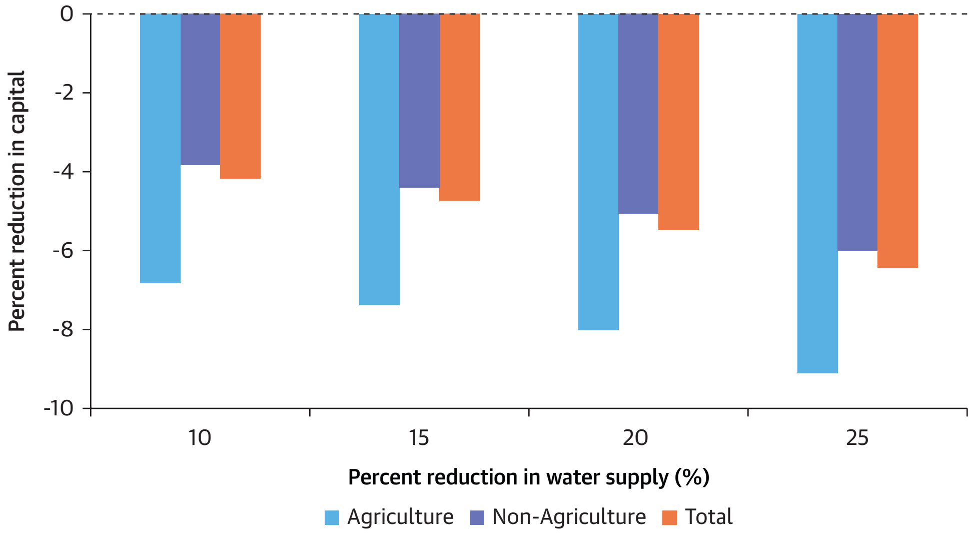
Impact on Capital

Permanent reductions in water supply could make a portion of exiting capital (representing private and public infrastructure, machinery, and durable equipment) idle in both agricultural and nonagricultural activities. Permanent reductions may also shift investment from agricultural to nonagricultural activities. When water supply and crop yields drop, the existing capital in agriculture will not operate at full capacity. Then, with lower production of agricultural products, nonagricultural activities that have forward and backward linkages with agricultural activities will not operate at full capacity. This creates idled capacity across the economy, at least in a medium-run time horizon. Figure 6.4 represents impacts of water scarcity in combination with changes in crop yields induced by climate change for SC1 to SC4 experiments. From the results shown in Figure 6.4, the following deductions can be made:

- Demand for capital in agricultural activities decreases as the level of water scarcity increases in agricultural activities, from about −6.8 percent with a 10.0 percent reduction in water supply to −9.0 percent with a 25.0 percent reduction in water supply.
- Demand for capital in nonagricultural activities drops, but at a lower rate compared with agriculture.
- At the national level, demand for capital drops from −4.2 percent with a 10.0 percent reduction in water supply to −6.4 percent for a 25.0 percent reduction in water supply.

Investment in WUE can partially restore idled capacities in a medium-run time horizon. For example, with a 25.0 percent reduction in water supply in the presence of yield changes because of climate change, a 20.0 percent improvement in WUE changes the rate of idled capacity from −9.0 to −7.9 percent in agricultural activities.

FIGURE 6.4. Impacts of 25 Percent Reduction in Water Supply with Crop Yield Changes on Capital Demand, SC1 to SC4



The long-run implications of climate change on idled capacity, and employment, could be different from those in the medium term. In the long run, climate conditions may worsen. However, economies may find more options to mitigate impacts of climate change, alter their production technology, and change their water use pattern.

Impacts on Harvested Area

The changes in irrigated and rainfed harvested areas vary significantly across examined cases. First, consider the obtained changes in irrigated and harvested areas when water supply drops in the absence of changes in crop yields induced by climate change (that is, cases C1 to C4) in figure 6.5.

In these cases, the harvested area of irrigated crops decreases, whereas the harvested area of rainfed crops increases. All other things being equal, the lower the amount of water for irrigation, the smaller the irrigated area. In this case, a portion of irrigated area becomes rainfed. In addition, rainfed crops have lower yields compared with their irrigated counterparts, which could induce some deforestation in areas where rainfed cropping can be expanded.

The results change when we bring the changes in crop yields induced by climate change into the picture (that is, cases SC1 to SC4), as presented in figure 6.2. In these cases, climate change promotes yields of irrigated crops and diminishes yields of rainfed crops. This alters the profitability of crop production in favor of irrigated crops and changes the mix of crops toward more valuable, more productive, and less water-intensive crops. This alteration generates a rebound effect in the irrigated area and expands it, particularly at lower levels of reductions in water supply, as shown in figure 6.6. As the level of reduction in water supply increases, the rate of the rebound effect in the irrigated area and the total harvested area per se drop.

We now bring the impacts of improvements in WUE into our analysis. An improvement in WUE (producing more crops per drop of water) allows an expansion in irrigated area. Figure 6.7 compares changes in irrigated area for SC1 to SC4 cases with their corresponding simulations, including a 20 percent

FIGURE 6.5. Changes in Irrigated and Rainfed Harvested Area, S1 to S4

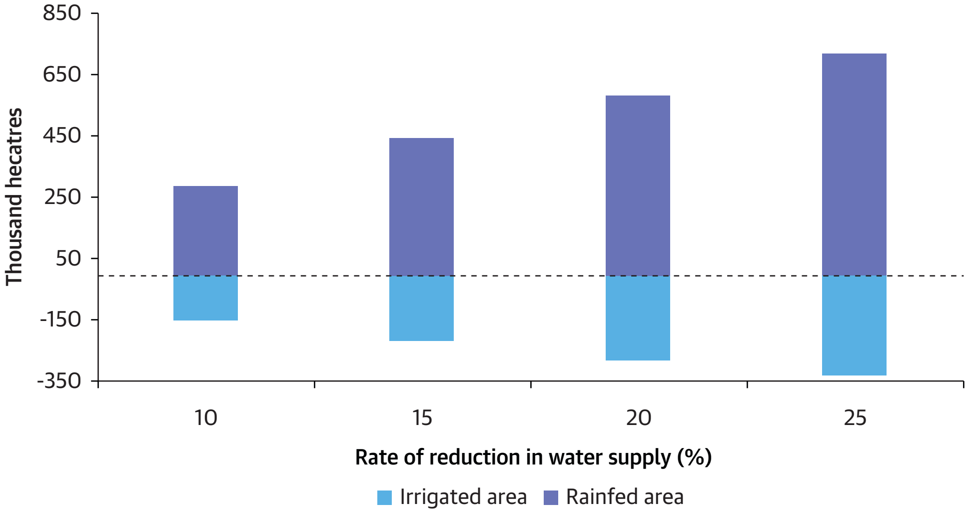


FIGURE 6.6. Changes in Irrigated and Rainfed Harvested Area, SC1 to SC4

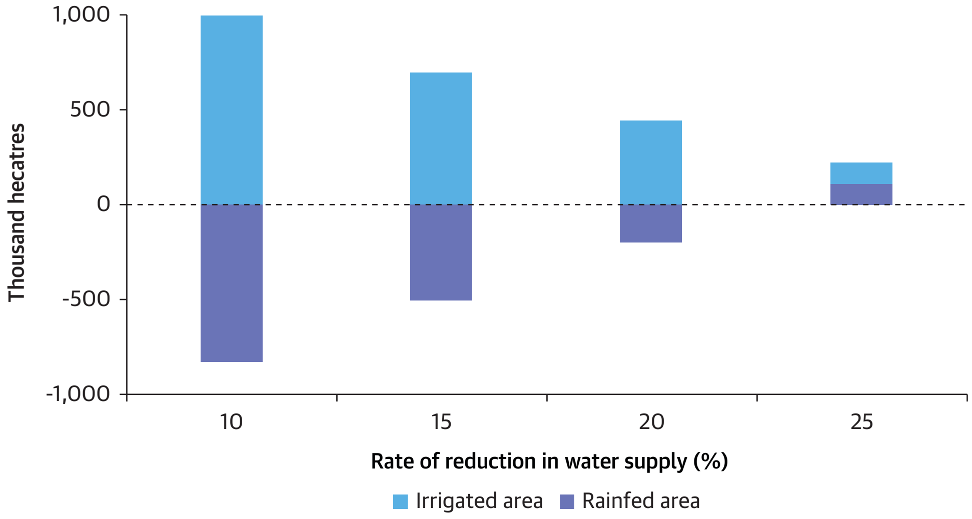
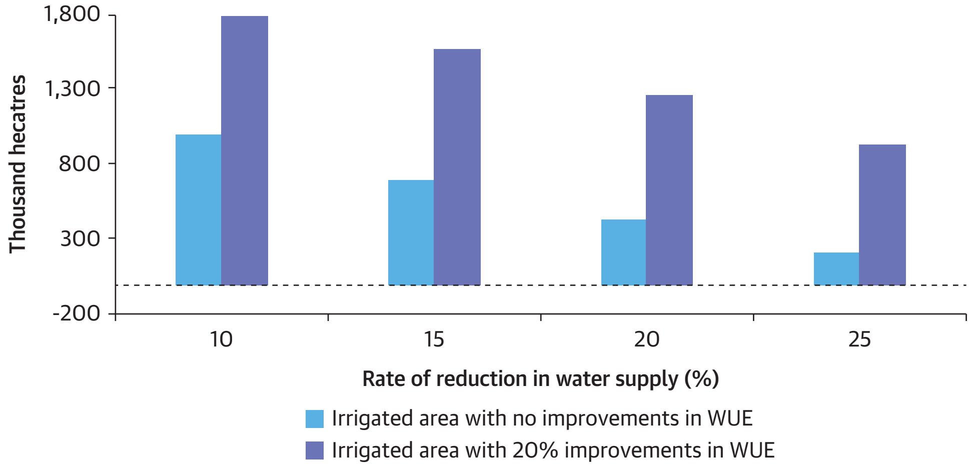


FIGURE 6.7. Changes in Irrigated Area, SC1 to SC4 and SC1-W20 to SC4-W20



improvement in WUE. It shows that in both cases, the change in irrigated area declines as the rate of reduction in water supply grows. However, with a 20 percent improvement in WUE, the changes in irrigated area are larger.

In contrast, with improvements in WUE, we expect more reduction in rainfed area, as demonstrated in figure 6.8. These results indicate that an improvement in WUE has the potential to expand irrigated area and reduce rainfed area. However, the expansion and reduction vary by the rate of reduction in water supply.

Reduction in water supply and changes in crop yields because of climate change jointly alter the crop shares in the total harvested area, as indicated in figure 6.9. These joint drivers drop the share of wheat in the total harvested area and elevate the shares of coarse grains, oilseeds, and vegetables and fruits. The share of wheat drops because of lower productivity in the presence of climate change. The expansion of the share of vegetables and fruits help the agricultural sector of Morocco to compensate for a portion of the losses in revenues from wheat production, because vegetables and fruits are usually higher-priced crops compared with wheat. This also helps Morocco to maintain its revenue stream obtained from exports of vegetables and fruits, as discussed later in this report.

FIGURE 6.8. **Changes in Rainfed Area, SC1 to SC4 and SC1-W20 to SC4-W20**

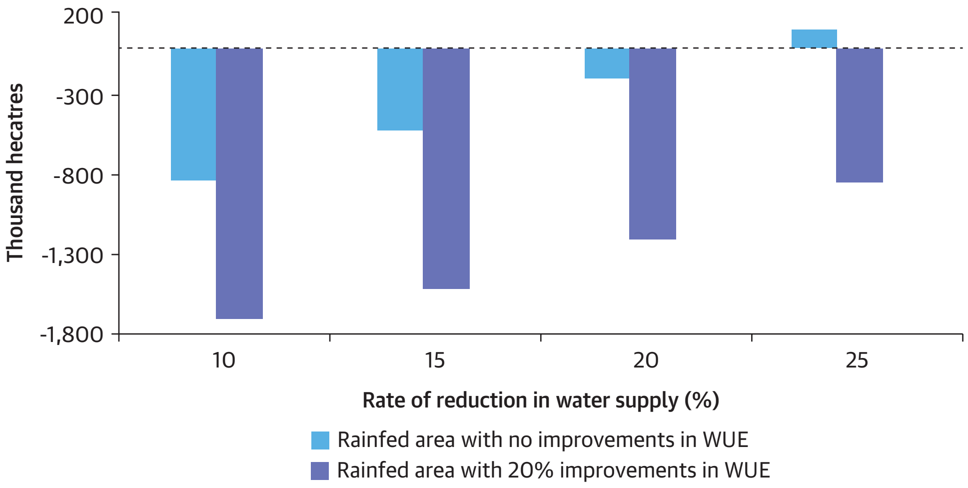
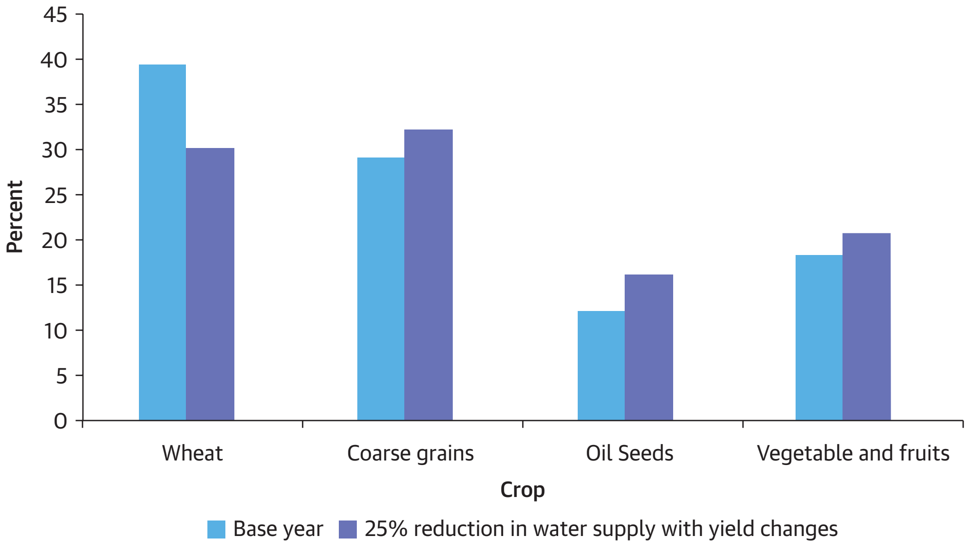


FIGURE 6.9. **Crop Shares in Total Harvested Area, Base Data versus SC4**



Impacts on Crop Prices

Changes in crop prices measured with producer and consumer price indexes for all examined cases are presented in table 6.5. From table 6.5, the following deductions can be made:

- Reduction in water supply increases crop prices; the greater the reduction in water supply, the higher the crop prices. With a 25 percent reduction in water supply, the producer and consumer price indexes grow by 10.3 and 5.7 percent, respectively, when we ignore the impacts of climate change on crop prices.
- Climate change, which will penalize rainfed crops, extends the price impacts sharply. Taking into account these impacts, with a 25 percent reduction in water supply, the producer and consumer price indexes grow by 15.9 and 8.7 percent, respectively.
- Improvements in WUE partially eliminate a small portion of price increases. This occurs because water scarcity is not the only sources of increase in crop prices. Reductions in crop yields because of climate change also contribute.
- Compared with the producer price index, the consumer price index grows at a lower rate because consumers use imported products too.

Although water scarcity and yield changes jointly increase all crop prices, the price impacts vary across crops. For instance, these factors jointly increase the producer prices of wheat, coarse grains, oilseeds, and vegetables and fruits by 11.5, 13.6, 20.1, and 15.9 percent, respectively. These figures indicate that the price increases are expected to be smaller for wheat and coarse grains compared with the price increases for oilseeds and vegetables and fruits. This can be explained partially by the crop trade pattern of Morocco. The country basically imports wheat and coarse grains, exports vegetables and fruits, and has no major trade for oilseeds. Morocco is expected to import more wheat and coarse grains from the world market because of water scarcity and losses in yields of these crops. This helps to mitigate the price impacts for these crops. The price increases for oilseeds will be sharper, because oilseeds will be produced domestically, continuing the existing pattern. For vegetables (including tomatoes, strawberries, and other berries) and fruits, the price impacts are expected to be strong as a portion of these crops exported to other countries.

TABLE 6.5. Changes in Producer and Consumer Prices for Crops under Alternative Scenarios

		Reduction in water supply			
Examined variable	**Examined case**	**10%**	**15%**	**20%**	**25%**
Changes in crops, producer price index (%)	S1 to S4	3.5	5.6	7.8	10.3
	SC1 to SC4	11.7	12.7	14.1	15.9
	SC1-W20 to SC4-W20	10.3	10.6	11.1	12.0
	SC1-W10 to SC4-W10	10.8	11.3	12.2	13.5
Changes in crops, consumer price index (%)	S1 to S4	2.0	3.1	4.4	5.7
	SC1 to SC4	6.5	7.0	7.7	8.7
	SC1-W20 to SC4-W20	5.8	5.9	6.2	6.6
	SC1-W10 to SC4-W10	6.0	6.3	6.8	7.4

Impact on Trade Balance of Food Products

Changes in the net trade of food products (including all crops, livestock, and processed food) for all examined cases are presented in table 6.6. From table 6.6, the following deductions can be made:

- Reduction in water supply reduces the net exports of food items; the greater the reduction in water supply, the larger the reduction in net exports. With a 25 percent reduction in water supply, net exports drop by $611 million per year at 2016 prices when we ignore the impacts of climate change on net exports.
- Climate change, which will negatively affect rainfed crops, reduces net exports. Taking into account these impacts, with a 25 percent reduction in water supply, the net exports are expected to drop by $891 million per year at 2016 prices.
- Improvements in WUE partially eliminate a small portion of the reduction in net exports of food items.

In short, as production of agriculture drops, Morocco is expected to export less and import more to and from other countries.

Although water scarcity and yield changes jointly decrease the net exports of all agricultural and food products of Morocco, a large portion of this reduction (more than 50 percent across the examined cases) falls on vegetables and fruits. This is because these crops are the main exporting crops of Morocco and they jointly consume a large portion of water for irrigation, particularly underground water. These crops may gain yield because of CO_2 concentration.

Impacts on Terms of Trade

As explained earlier in this paper, reduction in water supply and changes in crop yields because of climate change could significantly increase Morocco's agricultural and food prices. In this section, we examine the extent to which these price changes could affect the terms of trade. As shown in table 6.7, under all examined cases, the terms of trade alter in favor of Morocco slightly. For example, with a 25 percent reduction in water supply in the presence of changes in crop yields, the terms of trade increase by 1.5 percent in favor of Morocco. This slight increase indicates that Morocco could transfer a portion of increases in its agricultural and food products to its trade partners in a medium-run time horizon. This observation could be explained by Morocco basically exporting high-quality vegetables and fruits and some food products to other countries, particularly European countries. The customers of these

TABLE 6.6. Changes in Trade Balance of Food Items under Alternative Scenarios

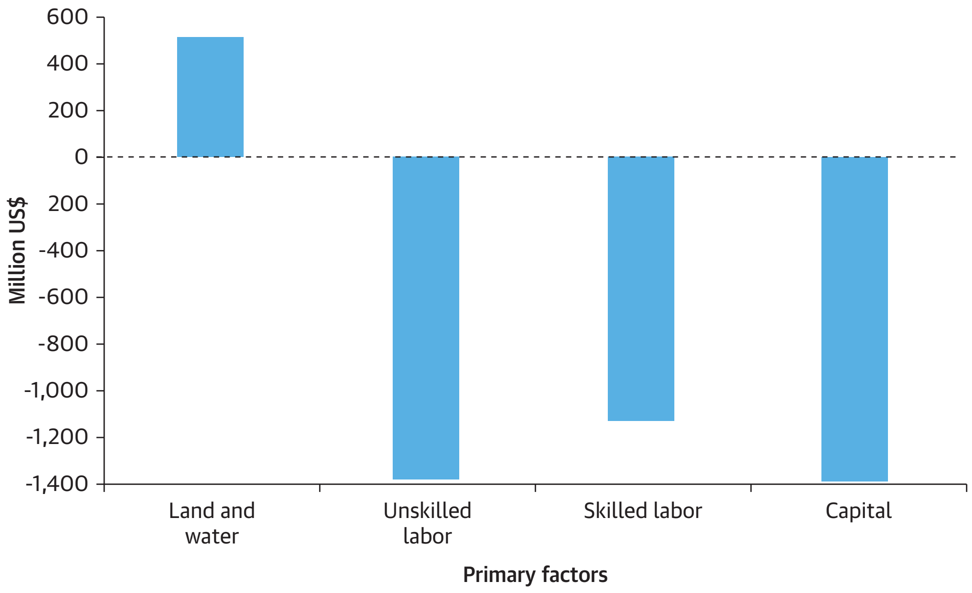
		Reduction in water supply			
Examined variable	**Examined case**	**10%**	**15%**	**20%**	**25%**
Changes in trade balance of food (US$, millions)	S1 to S4	−223	−345	−475	−611
	SC1 to SC4	−679	−728	−797	−891
	SC1-W20 to SC4-W20	−612	−627	−651	−692
	SC1-W10 to SC4-W10	−633	−661	−704	−768

Note: Food items include crops, livestock, and processed food.

TABLE 6.7. Changes in Terms of Trade under Alternative Scenarios

Examined variable	Examined case	Reduction in water supply			
		10%	15%	20%	25%
Changes in terms of trade (%)	S1 to S4	0.4	0.7	0.9	1.2
	SC1 to SC4	0.9	1.1	1.2	1.5
	SC1-W20 to SC4-W20	0.8	0.9	0.9	1.1
	SC1-W10 to SC4-W10	0.8	0.9	1.0	1.2

FIGURE 6.10. Changes in Incomes of Primary Factors of Production with 25 Percent Reduction in Water Supply and Crop Yield Changes



products could pay higher prices for their imports from Morocco in a medium-run time frame. However, this setup could change in a long-run time frame if the importing countries shift to other producers of these products.

Impacts on Incomes of Primary Sources

As discussed previously, reduction in water supply and changes in crop yields jointly reduce demand for unskilled labor, skilled labor, and capital. However, these forces lead to reduction in water supply and land retirement. Here we examine the extent to which these changes affect the incomes of these primary factors of production, as shown in figure 6.10. Figure 6.10 shows that a 25 percent reduction in water supply in combination with changes in crop yields improves the incomes of owners of land and water by about $514 million per year compared with the base year. This is because of increases in values of irrigated land and water. With a reduction in water supply, a portion of irrigated land may be retired or transferred to rainfed land. However, the value of the land that will remain under irrigation will increase. In addition, the value of water will increase. The overall changes constitute a net benefit for the owners of land and water resources in general. However, some owners of these resources will lose and some will win.

Figure 6.10 shows that skilled and unskilled labor are the main losers, with reduction in incomes by $1.380 million and $1.136 million per year, respectively. The owners of capital resources also lose, with reduction in income by $1.390 million per year. These figures indicate that labors are the main losers. Given that a large portion of these losses will occur in rural areas where agricultural production take place, rural areas will suffer the most from reductions in water supply and changes in crop yields induced by climate change.

Rebound Effect in Water Consumption

To examine the extent to which WUE generates a rebound effect in water consumption, here we assume that supply of water responds to changes in demand for water. As mentioned previously, we developed four simulations for improvements in WUE, from 5 to 20 percent by 5 percent increments, in the absence of changes in crop yields (cases R1 to R4) and with changes in crop yields (cases RC1 to RC4). If there is no rebound effect, an improvement in WUE should reduce water consumption at same the rate. For example, a 5 percent improvement in WUE should drop demand for water by 5 percent. If demand for water did not drop or increased, then that shows some rebound effect in water consumption.

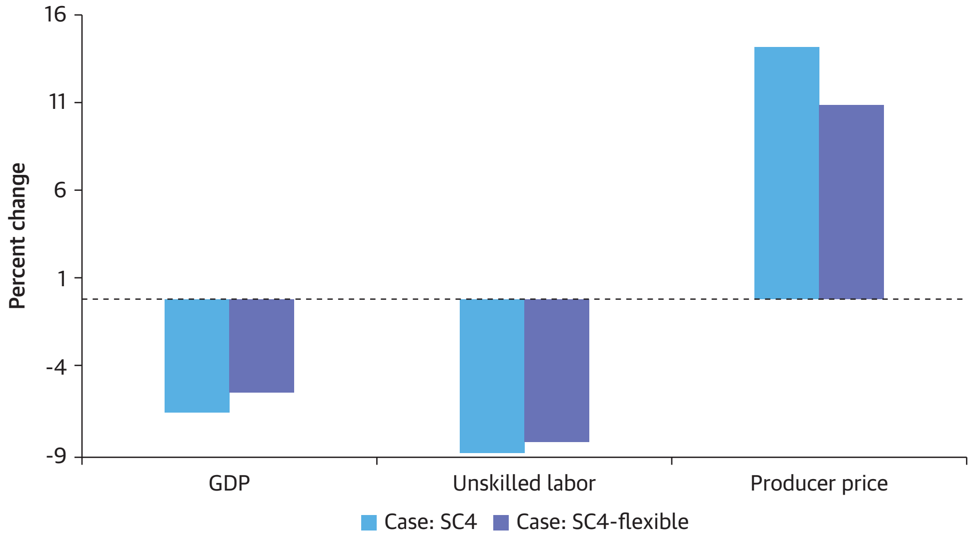
Table 6.8 shows the results for the examined cases. Table 6.8 indicates that in the absence of changes in rainfed crop yields, a 5 percent improvement in WUE reduces demand for water by 3.5 percent. This means a rebound effect of 1.5 percent (equal to 5.0 minus 3.5 percent) in water consumption. This figure increases to 7.5 percent with a 20 percent improvement in WUE. Hence, in these cases an improvement in WUE generate some saving in water consumption but at a rate less than the change in WUE.

When we take into account that climate change will punish rainfed crops, which generates additional demand for irrigation, an improvement in WUE does not lead to savings in water. In this case, an improvement in WUE generates additional demand for water. For example, as shown in table 6.8, a 5 percent improvement in WUE increases demand for water by 4.1 percent. This means a rebound effect of 9.1 percent (equal to 5.0 plus 4.1 percent) in water consumption. The corresponding figure for a 20 percent improvement in WUE is about 17.0 percent.

TABLE 6.8. Potential Rebound Effect in Water Consumption

		Rate of improvement in WUE			
Examined case	**Examined variable**	**5%**	**10%**	**15%**	**20%**
Only WUE: R1 to R4	Change in demand for water (%)	−3.5	−6.7	−9.7	−12.5
	Rebound effect (%)	1.5	3.3	5.3	7.5
WUE and changes in crop yields: RC1 to RC4	Change in demand for water (%)	4.1	1.4	−0.9	−3.0
	Rebound effect (%)	9.1	11.4	14.1	17.0

FIGURE 6.11. Impacts of Flexibility in Model Parameters on Simulation Results



Hence, if water supply can increase, climate change that will drop yields for rainfed crops could extend demand for irrigation, which leads to more water withdrawal, at least in the short run, in the absence of regulation on water withdrawal from underground resources or even from surface water.

Flexibility in Water Use and More Substitution among Inputs

Finally, consider a case in which we allow water to move between agricultural and nonagricultural uses and we take into account that in the long run, more substitutions occur among primary production factors. In this case, we repeat the case of RC4 (25 percent reduction in water supply with changes in crop yields), we assume water can move between agricultural and nonagricultural uses at a transformation rate of 0.5 (instead of nearly zero), and we use the GTAP long-run standard substitution elasticities among primary inputs in crop production. As mentioned previously, we refer to this case as RC4-Flexible.

Here we compare the results of SC4 with SC4-Flexible for three variables: percent change in the GDP, percent change in the demand for unskilled labor, and percent change in the producer price index. Figure 6.11 shows that the adverse impacts of water scarcity and climate decrease as we use a set of more flexible parameters in our simulation process. This provides two important insights:

- As usual, the result is sensitive to the implemented parameters. This calls for more sensitivity analyses to construct confidence intervals for the examined scenarios.
- In the long run, with technological progress in crop production (captured by larger substitutions), the Moroccan economy may be able to mitigate more efficiently some adverse impacts of climate change and water scarcity.

Chapter 7
Water and Businesses

Finally, we turn to new evidence that shows how, and how much, water affects job growth in cities using statistical techniques (not CGE simulations). In cities, the World Bank's business enterprise surveys (BESs)—considered the most comprehensive database on company-level inputs and outputs—are used for the analysis. Although the BES mission is in the process of collecting the next round of business data, the 2013 BES data—comprising of 187 manufacturing companies—is used to provide a retrospective look at the impacts of rainfall shocks and water supply interruptions on employment and sales. First, it was found that dry rainfall episodes significantly affect water outages faced by manufacturing companies in cities. In turn, increases in the number and duration of water outages lead to lower employment growth. Experiencing one additional water outage in a typical month decreases employment growth by 2.3 percentage points, and for each additional hour that a water outage lasts, employment growth is, on average, 2.3 percentage points lower. Furthermore, there is an overall dip in the productivity of companies and in business sales for companies that use water for business activities. With looming water challenges, issues of water infrastructure quality can be expected to worsen, with important implications for company productivity.

Chapter 8
Conclusion

Morocco is a country that has historically depended on agriculture. Even though agriculture normally represents only about 15 percent of the GDP, close to 40 percent of employment is in agriculture or related to agriculture, so changes in agricultural output because of changes in water availability and crop yields have a pronounced impact on the GDP. The purpose of this analysis has been to examine and quantify to the extent possible future impacts of changes in water availability, changes in crop yields because of climate change, and impacts of investments in improved WUE. We know the directions of all changes:

- Reduced water supply leads to a lower GDP.
- Impacts of climate change on crop yields result in a lower GDP.
- Increased water efficiency results in an increase in the GDP.

Thus, the value added in this analysis quantifies the magnitudes of the impacts of some of these changes and explores how these key drivers interact when simulated together.

Morocco is expected face a major water shortfall and reduction in rainfed crop yields prompted by climate change. Reduction in available water for irrigation and lower crop yields could negatively affect agricultural and nonagricultural activities in Morocco, which could lead to adverse economywide impacts. This research uses a CGE model, GTAP-BIO-W, to examine these impacts. This CGE model has been frequently used to examine the economywide impacts of water scarcity and climate change. In this research, we developed and examined a range of alternative scenarios that portray the economy of Morocco under different water scarcity scenarios mixed with climate impacts on crop yields and alternative sets of economic parameters that jointly govern allocation of water across uses.

The results obtained from these scenarios indicate the following:

- Reduction in water supply and changes in crop yields induced by climate change can jointly reduce the GDP of Morocco significantly. For instance, a 25 percent reduction in water supply in combination with changes in crop yields could jointly reduce the GDP of Morocco by $6.736 million per year at 2016 constant prices.
- The share of agriculture in the GDP of Morocco is expected to fall from 13.0 percent in 2016 to about 10.5 percent in the presence of a 25 percent reduction in water supply combined with climate impacts on crop yields.
- Demand for labor, particularly in the agricultural sector, is expected to fall in response to water scarcity and changes in crop yields. For instance, a 25 percent reduction in water supply in combination with changes in crop yields could jointly reduce the demand for unskilled labor in agricultural activities by 8.8 percent. For this case, the overall reduction in demand for labor is expected to be about 6.1 percent.

- Reduction in supply of water is expected to reduce irrigated area. However, changes in crop yields induced by climate change will encourage farmers to move toward more productive and less water-intensive crops. This could prevent reduction in irrigated area to some extent.
- Climate change would reduce yields of rainfed crops and increase yields of some irrigated crops because of CO_2 fertilization. Thus, rainfed crops, which include staple crops such as wheat and barley, would be more affected. Morocco would become more dependent on imports for these commodities.
- Crop prices are expected to increase for both crop producers and consumers. However, crop prices are expected to increase at a lower rate for consumers. This is because Morocco will import more and export less of its crop products.
- Improvements in WUE could eliminate impacts of water scarcity. Additional mitigation policies are needed to deal with the adverse impacts of climate change on rainfed crop yields.
- Improving WUE is important for Morocco. The experiments examined in this paper indicate that in the presence of water scarcity and change in crop yields because of climate change, a 20 percent improvement in WUE could lead to an increase in irrigated area by 708,000 hectares, with an increase in the GDP at constant prices by $1.8 billion per year, which translates to an annual increase in value added of $2.602 per hectare of new irrigated land per year. These gains are large enough to cover the costs of investment in irrigation technologies in a short period.
- In the long run, with technological progress in crop production, the Moroccan economy may be able to mitigate more efficiently some adverse impacts of climate change and water scarcity.

The examined experiments in this paper assume no changes in agricultural and trade policies. Changes in these policies could alter the results. It is important to develop experiments to examine interplay among climate change, water scarcity, and changes in agricultural and trade policies. Currently, Morocco's trade policies protect domestic production of several water-intensive crops. Morocco produces these crops at higher costs compared with world market prices. Removing these trade restrictions could help the agricultural sector of Morocco to move toward less water-intensive and exporting crops (vegetables and fruits) that Morocco has relative advantages to produce.

Morocco has made substantial progress over the years in moving its economy toward a market orientation. As in many countries, agriculture and food lag behind other sectors in these reforms. Some adverse consequences of climate change or reduction of water supply may help to induce Morocco to move in a direction of more efficient use of its scarce water resources.

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Appendix A

List of GTAP Sectors and Proposed Aggregation for Morocco

Number	Code	Description	Aggregation for Morocco
1	pdr	Paddy rice	Two sectors of pdr irrigated and pdr rainfed
2	wht	Wheat	Two sectors of wht irrigated and wht rainfed
3	gro	Other grains: maize (corn), barley, rye, oats, other cereals	Two sectors of gro irrigated and gro rainfed
4	osd	Oilseeds: oilseeds and oleaginous fruit, soybeans, copra	Two sectors of osd irrigated and osd rainfed
5	c_b	Cane and beet: sugarcane, sugar beet	Two sectors of c_b irrigated and c_b rainfed
6	v_f	Vegetables and fruits: vegetables, fruits, nuts, potatoes, cassava, truffles	Two sectors of irrigated and rainfed vegetables and two sectors of irrigated and rainfed fruits and others
7	pfb	Plant fibers: cotton, flax, hemp, sisal, other raw vegetable materials used in textiles	
8	ocr	Other crops: live plants; cut flowers and flower buds; flower seeds and fruit seeds; vegetable seeds; beverage and spice crops; unmanufactured tobacco; cereal straw and husks, unprepared, whether chopped, ground, pressed, or in the form of pellets; swedes, mangolds, fodder roots, hay, lucerne (alfalfa), clover, sainfoin, forage kale, lupines, vetches and similar forage products, whether in the form of pellets, plants, and parts of plants used primarily in perfumery, in pharmacy, or for insecticidal, fungicidal, or similar purposes; sugar beet seed and seeds of forage plants; other raw vegetable materials	
9	ctl	Cattle: cattle, sheep, goats, horses, asses, mules, hinnies, and semen thereof	Ruminant
10	oap	Other animal products: swine, poultry, and other live animals; eggs in shell (fresh or cooked); natural honey; snails (fresh or preserved), except sea snails; frogs' legs; edible products of animal origin n.e.c., hides, skins, and fur skins, raw; insect waxes and spermaceti, whether refined or colored	Nonruminant
11	rmk	Raw milk	Dairy farm
12	wol	Wool: wool, silk, other raw animal materials used in textile	Nonruminant
13	frs	Forestry: forestry, logging, related service activities	Forestry

table continues next page

Number	Code	Description	Aggregation for Morocco
14	fsh	Fishing: hunting, trapping, and game propagation, including related service activities; fishing; fish farms; service activities incidental to fishing	Food
15	coa	Coal: mining and agglomeration of hard coal, lignite, and peat	Coal
16	oil	Oil: extraction of crude petroleum and natural gas (part); service activities incidental to oil and gas extraction, excluding surveying (part)	Oil
17	gas	Gas: extraction of crude petroleum and natural gas (part); service activities incidental to oil and gas extraction, excluding surveying (part)	Gas
18	omn	Other mining: mining of metal ores, uranium, and gems; other mining and quarrying	Industry
19	cmt	Cattle meat: fresh or chilled meat and edible offal of cattle, sheep, goats, horses, asses, mules, and hinnies; raw fats or grease from any animal or bird	Possessed ruminant
20	omt	Other meat: pig meat and offal; preserves and preparations of meat, meat offal, or blood; flours, meals, and pellets of meat or inedible meat offal; greaves	Possessed nonruminant
21	vol	Vegetable oils: crude and refined oils of soybean, maize (corn), olive, sesame, groundnut, olive, sunflower seed, safflower, cottonseed, rape, colza and canola, mustard, coconut palm, palm kernel, castor, tung jojoba, babassu, and linseed, perhaps partly or wholly hydrogenated, interesterified, reesterified, or elaidinized; margarine and similar preparations; animal or vegetable waxes; fats and oils and their fractions; cotton linters; oil cake and other solid residues resulting from the extraction of vegetable fats or oils; flours and meals of oilseeds or oleaginous fruits, except those of mustard; degras and other residues resulting from the treatment of fatty substances or animal or vegetable waxes	Vegetable oils
22	mil	Milk: dairy products	Possessed dairy
23	pcr	Processed rice: rice, semi- or wholly milled	Food
24	sgr	Sugar	Sugar and beverage

table continues next page

Number	Code	Description	Aggregation for Morocco
25	ofd	Other food: prepared and preserved fish or vegetables; fruit juices and vegetable juices; prepared and preserved fruit and nuts; all cereal flours, groats, meal and pellets of wheat, cereal groats, and meal and pellets n.e.c.; other cereal grain products (including cornflakes); other vegetable flours and meals; mixes and doughs for the preparation of bakers' wares, starches and starch products; sugars and sugar syrups n.e.c.; preparations used in animal feeding, bakery products, cocoa, chocolate and sugar confectionery, macaroni, noodles, couscous and similar farinaceous products, food products n.e.c.	Food
26	b_t	Beverages and tobacco products	Sugar and beverage
27	tex	Textiles: textiles and manmade fibers	Industry
28	wap	Wearing apparel: clothing, dressing, dyeing of fur	
29	lea	Leather: tanning and dressing of leather, luggage, handbags, saddlery, harness, footwear	
30	lum	Lumber: wood and products of wood and cork, except furniture; articles of straw and plaiting materials	
31	ppp	Paper and paper products: includes publishing, printing, and reproduction of recorded media	
32	p_c	Petroleum and coke: coke-oven products, refined petroleum products, processing of nuclear fuel	
33	crp	Chemical rubber products: basic chemicals, other chemical products, rubber and plastic products	
34	nmm	Nonmetallic minerals: cement, plaster, lime, gravel, concrete	
35	i_s	Iron and steel: basic production and casting	
36	nfm	Nonferrous metals: production and casting of copper, aluminum, zinc, lead, gold, and silver	
37	fmp	Fabricated metal products: sheet metal products, but not machinery and equipment	
38	mvh	Motor vehicles and parts: cars, lorries, trailers, semitrailers	
39	otn	Other transport equipment: manufacture of other transport equipment	

table continues next page

Number	Code	Description	Aggregation for Morocco
40	ele	Electronic equipment: office, accounting, and computing machinery; radio, television, and communication equipment and apparatus	
41	ome	Other machinery and equipment: electrical machinery and apparatus n.e.c.; medical, precision, and optical instruments; watches and clocks	
42	omf	Other manufacturing: includes recycling	
43	ely	Electricity: production, collection, distribution	Two sectors of hydroelectricity and nonhydroelectricity
44	gdt	Gas distribution: distribution of gaseous fuels through mains, steam and hot water supply	Gas
45	wtr	Water: collection, purification, distribution	Managed water
46	cns	Construction: building houses, factories, offices, and roads	Construction
47	trd	Trade: all retail sales; wholesale trade and commission trade; hotels and restaurants; repairs of motor vehicles and personal and household goods; retail sale of automotive fuel	Service
48	otp	Other transport: road, rail, pipelines, auxiliary transport activities,; travel agencies	Transportation
49	wtp	Water transport	
50	atp	Air transport	
51	cmn	Communications: postal communications, telecommunications	Service
52	ofi	Other financial intermediation: includes auxiliary activities but not insurance and pension funding (see next)	
53	isr	Insurance: includes pension funding, except compulsory social security	
54	obs	Other business services: real estate, renting, business activities	
55	ros	Recreation and other services: recreational, cultural, and sporting activities; other service activities; private households with employed people (servants)	
56	osg	Other services (government): public administration and defense; compulsory social security, education, health and social work, sewage and refuse disposal, sanitation, and similar activities; activities of membership organizations n.e.c.; extraterritorial organizations and bodies	
57	dwe	Dwellings: ownership of dwellings (imputed rents of houses occupied by owners)	

Note: n.e.c. = not elsewhere classified.

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